SHARK NURSERY GROUNDS AND ESSENTIAL FISH HABITAT STUDIES

GULFSPAN GULF OF MEXICO-FY04
Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey

REPORT TO NOAA FISHERIES, HIGHLY MIGRATORY SPECIES OFFICE

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BACKGROUND

Identification and conservation of essential fish habitat are important components of providing adequate management and conservation for shark populations. This is of particular importance when attempting to understand the dynamics of sharks in coastal nursery areas. This report describes results from the Cooperative Gulf of Mexico Shark Pupping and Nursery Project (GULFSPAN) for 2004.

METHODS

Surveys were modeled after those developed by Carlson and Brusher (1999) to provide a direct comparison of abundance among areas. A 186-m long gill net consisting of six different mesh size panels was utilized for sampling in all areas. Stretched mesh sizes ranged from 8.9 cm (3.5") to 14.0 cm (5.5") in steps of 1.27 cm (0.5"). The sampling gear was set at fixed stations or randomly set within each area based on depth strata and GPS location. Sharks captured were measured (precaudal, fork, total, stretched total length), sexed, and life history stage (young-of-the-year, juvenile, adult) recorded. Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged with a nylon-head dart tag and released. Rays that were captured were measured in disc width and sexed. Because of the limited life history information for most species, a life history category for rays could not always be assigned in the field. Temperature, salinity, dissolved oxygen, depth, water clarity (e.g. turbidity), and qualitative habitat type was recorded for each set of the gear.

RESULTS

1. Northwest Florida

Abundance trends

Sampling sites were located in four major areas along the northeastern portion of the Gulf of Mexico from St. Andrews Bay, FL, to Apalachicola Bay, FL (Figure 1). Sampling was conducted from April to October. A total of 117 sets were made capturing individuals from 11 species of sharks and 3 species of rays. For sharks, most species captured were juveniles and young-of-the-year (Table 1).

Among sharks for all areas combined, the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, a member of the small coastal management group, was the most abundant shark captured, and the blacktip shark, *Carcharhinus limbatus*, was the most abundant species captured in the large coastal management group. The bonnethead shark, *Sphyrna tiburo*, was the second most abundant species captured in the small coastal group and overall was the third most encountered species. The remaining species commonly captured in decreasing abundance were the finetooth shark, *C. isodon*, spinner shark, *C. brevipinna*, scalloped hammerhead shark, *S. lewini*, blacknose shark, *C. acronotus*, and sandbar shark, *C. plumbeus.* Other species infrequently caught were bull shark, *C. leucas*, Florida smoothhound, *Mustelus norrissi*, and great hammerhead shark, *S. mokarran*.

Cownose rays, *Rhinoptera bonasus*, were the most abundant ray captured. Other ray species captured in decreasing abundance were bluntnose stingray; *Dasyatis sayi* and Atlantic stingray, *D. sabina* (Table 2).

Species Essential Fish Habitat Profiles

Habitat associations for northwest Florida are summarized in Tables 3-14. New information on temperature profiles and habitat preferences was obtained during 2004. Florida smoothhound shark, a species generally thought to occur more in cooler waters, were captured in temperatures up to 28.8˚ C.

Predator-prey and trophic relationships

Atlantic sharpnose shark diet was described from Crooked Island Sound, an embayment of the northeast Gulf of Mexico. Diet was assessed by life-stage and quantified using six indices: percent by number, percent by weight, frequency of occurrence, the index of relative importance (IRI), IRI expressed on a percent basis (%IRI), and %IRI based on prey category (%IRI_{PC}). Young-of-the-year sharks (n=56) fed on a mix of teleosts (mostly clupeids, 44.6 %IRI_{PC}) and invertebrates (combined, 25.1 %IRI_{PC}), juveniles (n=185) on sciaenids (40.7 %IRI_{PC}) and clupeids (37.8 %IRI_{PC}), and adults (n=105) on sciaenids (71.4 %IRI_{PC}). Differences in diet by site and ontogeny were tested by comparing diet from Crooked Island Sound with published information from St. Vincent Island in Apalachicola Bay, an adjacent estuary. Stomach contents were also used to expand on published prey size-predator size information. Spearman correlation analysis indicated ontogenetic diet shifts within each site. In addition, simple correspondence analysis showed that life stage diet differed between sites. Three of four size-selectivity tests showed negative size selection. Absolute prey size and the range in absolute prey size increased with increasing shark size. Atlantic sharpnose sharks consume considerable amounts of intermediate-sized prey while still feeding on small-sized prey. Variations in diet composition within and between the two sites are likely due to differences in overall habitat structure and availability of potential prey species. Results of this study are currently in review in the journal Bulletin of Marine Science (Bethea et al., In review).

Telemetry

In May 2004, an array of stationary underwater acoustic receivers (VEMCO Ltd. VR1) was placed in a habitat where young-of-the-year and juvenile blacktip and Atlantic sharpnose sharks occur during summer months (Crooked Island Sound, FL). This array network monitors a combined area of 30 km^2. The array consists of 12 acoustic receivers and has been used to nearly continuously monitor movements of individuals for periods over one year. The data collected by this system are currently being used in a broad range of studies to help better understand the role of elasmobranchs within the estuary, study changes in habitat use through time, examine intra and interspecific relationships (e.g. predator-prey, competition, group dynamics), and determine how anthropogenic disturbance (related to water use patterns and habitat alteration) impact elasmobranch resource utilization. Preliminary data collected shows some habitat overlapping at both temporal and spatial scales. In addition to general distribution and movement data, the acoustic array also revealed responses of individuals to extreme environmental disturbance. During 2004, Hurricane Ivan made landfall approximately 58 km from Crooked Island Sound. In the days prior to the storm making landfall, all of the sharks being monitored within the study site left and moved into the deeper waters of the Gulf of Mexico. Similar to that found in Heupel et al. (2003), the change in barometric pressure is hypothesized to have caused the sharks to leave the study site. This study will continue in 2005.

2. Mississippi/Alabama

A total of 33 sets at eight sampling stations were performed from July to October 2004 in

Mississippi coastal waters (Figure 2). A total of 61 sharks were collected, representing four species, 75% of which were immature (Table 15). The blacktip shark, *C. limbatus*, was the most abundant species caught followed by the Atlantic sharpnose shark, *R. terraenovae*, finetooth shark, *C. isodon*, and bull shark, *C. leucas*.

Horn Island was the most productive location (3.1 ± 1.3 sharks net hr^{-1}), followed by Round Island (1.5 sharks net hr^{-1}), Cat Island (0.8 ± 0.6 sharks net hr^{-1}), and Davis Bayou (0.33 sharks net hr^{-1}). For all combined life stages, blacktip and Atlantic sharpnose sharks were most abundant off Horn Island while finetooth and Atlantic sharpnose sharks were most frequently caught off Round Island. Blacktip, bull, and finetooth sharks were all collected in waters north of Cat Island. The bull shark was the only species collected from Davis Bayou.

Species Essential Fish Habitat Profiles

Information on essential fish habitat requirements (e.g. temperature, salinity, etc.) for the four shark species were similar (Tables 16-18), primarily because they were all sampled within a relatively short period of time. There were a few interesting observations. The majority of sharks collected in this study were immature, suggesting that Mississippi Sound is an important nursery area for several shark species. This also suggests that Mississippi Sound is not a suitable habitat for adult sharks, which may prefer deeper, cooler waters. The majority of the sharks were collected in higher salinity waters (23.6 – 27.6 ‰, Tables 2-5); however, only young-of-the-year bull sharks and adult blacktip were collected in 18 ‰. This was not unexpected for young bull sharks, since they appear to prefer lower salinity environments. However, the low salinity was unusual for the adult blacktip.

3. Louisiana

Methodology and data summary

A total of nine gillnet sets at seven stations were made from 22 May to 17 July 2004 in Timbalier Bay, central Louisiana (Figure 3). Six 33-m, multi-mesh gillnet panels anchored on both ends were deployed for one hour periods throughout a 24 hour period. An additional three sets were completed using only four large mesh (20 cm stretch mesh), 30-m long gillnets following the methodology of Blackburn (2003) specifically to capture bull sharks in Devil's Bay, a smaller bay within Timbalier Bay. Again the only change between the current sampling and that of Blackburn (2003) was the length of sampling. Blackburn (2003) sampled continuously from dusk until dawn with continuous net checks while the net was still anchored, whereas in the current study, the net was set for one hour and retrieved at the end of that period.

The northeastern end of East Casse Tete Island was determined to be an area of temporally stable high shark capture abundance for the bull shark, *Carcharhinus leucas,* the blacktip shark*, C. limatus*, the Atlantic sharpnose shark*, Rhizoprionodon terraenovae*, in the previous study by Neer et al. (In press) and selected as a permanent sampling station. The additional sampling sites in the 2004 sampling year were randomly selected. Neer et al. (in press) developed a GIS-based gridded surface of Timbalier Bay for a kernel density analysis, which was used to identify areas of high shark capture rates. That grid was used to develop a random sampling scheme for the 2004 sampling year. A centroid was assigned to each grid cell within the GIS and then randomly sampled using SPSS. Those grid cell locations were loaded into a Personal Data Assistant (PDA: Compaq Ipaq 3800 series) running ArcGIS 6.0 software and a CF-GPS unit (Teletype Corporation) for navigation in the field. Random sites were evaluated within the GIS and in the field for obstructions (e.g. oil platforms), water depth, and boat traffic, and then fished as weather permitted. Weather and boat maintenance were limiting factors in sampling in the 2004 year. High winds and rough waters were predominant on all sampling trips, limiting the sampling to sites within the upper reaches of the bay. No sets were made on the Gulf of Mexico (GOM) side of the barrier islands in 2004 due to poor weather conditions on all sampling trips. Two attempts were made to fish the GOM side of the islands with no successful net deployments.

Three species of sharks were caught in the 2004 sampling season; most species captured were juveniles (Table 23). The blacktip shark, *Carcharhinus limbatus*, was the most abundant species caught (n = 67) followed by the bull shark, *C. leucas*, (n = 7). A single adult specimen of the finetooth shark, *C. isodon*, and a single healed-scar, young-of-the-year Atlantic sharpnose shark, *R. terraenovae*, were also collected in Timbalier Bay. No sphyrnid, spinner, or lemon sharks were collected in 2004, though all three were collected between 1999 and 2001 (Neer et al. In Press). The blacktip shark, Atlantic sharpnose, and bull shark were the three most common species captured by Neer et al. (In Press) from 1999 to 2001. For comparative purposes, CPUE for the 2004 sampling year was calculated for blacktip sharks following to Neer et al. (In Press) as the total number of sharks (by individual species) divided by the total fishing time in hours. Blacktip sharks had a mean CPUE of 8.43 sharks/hour for the whole season. This value is inflated due to a single set on 23 June 2004 with 57 sharks collected in 2.83 hours of net soak time.

The largest single collection of blacktip sharks (n = 56) was made in the western end of Devil's Bay on the morning of 23 June 2004. The remaining blacktip sharks were collected on the northeastern end of Casse Tete Island and in the open bay. The largest collection of bull sharks (n = 5) was collected using the large mesh gillnet (20 cm stretch mesh) in the southwestern end of Devil's Bay at dusk on 17 July 2004. Two of the five bull sharks were released with NMFS M-style tags from the Narragansett Lab (1 995 mm FL male; 1 950 mm FL female). The remaining bull shark was collected on the northeastern end of Casse Tete Island and released with a NMFS M-style tag from the Narragansett Lab. The single sample of bull sharks in Devil's Bay in 2004 had a CPUE of 5.0. The single finetooth shark was collected on 23 June 2004 on the western side of Devil's Bay and transported on ice to the Coastal Fisheries Institute at LSU for museum curation. Though limited data were collected in 2004, species present and catch rates were similar to those of Neer et al. (In press) for 1999 – 2001, with the exception of the Atlantic sharpnose shark that had higher incidence of capture from 1999 – 2001 than in 2004.

Species Essential Fish Habitat Profiles

Information on essential fish habitat requirements (e.g. temperature, salinity, etc.) for sharks is summarized in Tables 24-27. Timbalier Bay remains an area of high catch abundance for blacktip sharks as in 1999-2001. Bull shark catch rates using larger mesh gear are comparable with Blackburn (2003) catch numbers.

CONCLUSIONS

New information on habitat preferences and essential fish habitat is emerging as this study concludes its second year. Juvenile bonnethead sharks appear to prefer habitat dominated by seagrass (in northwest Florida) or mangroves (Louisiana). In areas where neither of these habitat types is available, juvenile bonnetheads are in very low numbers or absent (i.e. Mississippi Sound). Adult Bonnethead sharks, however, are found in diverse habitats ranging from areas with a mud or sand bottom to areas dominated by seagrass. Evidence from the habitat association tables indicates bull sharks are found among the most diverse environmental conditions with salinities ranging from 15 ppt (in Louisiana and Mississippi) to 33 ppt (in northwest Florida) and over all habitat types.

Juvenile sandbar sharks are still predominately caught in the northwest Gulf of Mexico while blacktip, finetooth, and Atlantic sharpnose sharks are found throughout all areas. Although bull sharks can be found over a variety of habitats, the areas of highest abundance are those adjacent to freshwater inflow.

More information critical to Essential Fish Habitat continues to be developed regarding trophic relationships and feeding habitats in sharks. Atlantic sharpnose sharks consume considerable amounts of intermediate-sized prey while still feeding on small-sized prey. Variations in diet composition within and between the nursery areas are due to differences in overall habitat structure and availability of potential prey species. Quantitative examination of feeding ecology from different proposed nurseries is one way to begin to understand how juvenile sharks use nursery habitats and determine which habitat types have higher "nursery value" than others (sensu Beck et al., 2001). For example, young-of-the-year Atlantic sharpnose sharks have very different diets depending on area. This could affect growth. Based on the metabolic rate of the similarly-sized blacknose shark *Carcharhinus acronotus* (Carlson et al., 1999) and assuming 27% of consumed energy is lost as waste (Wetherbee and Cortés, 2004), a 0.9 kg young-of-the-year Atlantic sharpnose shark feeding on clupeids in Crooked Island Sound would have to eat 2.6 % of its body weight per day just to maintain its weight. The same shark occupying the Apalachicola Bay system and feeding on a diet primarily of shrimp would have to eat 5.2 % of its body weight per day to maintain its weight. Thus, sharks in the Apalachicola Bay system may require higher ration levels to fulfill energetic need. This could translate into less energy available for growth (or possible starvation) if consumption rates are not maintained. Although this is a simplified model of an energy budget, preliminary evidence suggests Crooked Island Sound provides a greater "nursery value" (Beck et al., 2001) than St. Vincent Island and the Apalachicola Bay system. Further studies on growth and survival of juvenile sharks are required to validate this hypothesis.

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Table 1. Summary of CPUE (number of sharks/net/hour) for sharks by life history stage and major area sampled in the northeast Gulf of Mexico. Means (standard deviations) are presented. Young-of-the-year life stage includes neonates. Specimens with an undetermined life stage are included in total CPUE calculation. Species are listed alphabetically by common name.

Atlantic sharpnose shark, *Rhizoprionodon terraenovae*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	0.12 (0.45)	0.03 (0.19)	0.23 (0.42)
Juveniles	-	0.97 (2.07)	0.31 (0.71)	0.30 (0.71)
Adults	-	1.10 (1.74)	0.02 (0.09)	0.82 (1.36)
All	-	2.23 (3.30)	0.38 (0.74)	1.36 (1.61)

Blacknose shark, *Carcharhinus acronotus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	0.06 (0.24)	0.03 (0.17)	0.31 (0.66)	-
Juveniles	-	-	0.03 (0.130	-
Adults	-	-	-	0.14 (0.51)
All	0.06 (0.24)	0.03 (0.17)	0.34 (0.67)	0.14 (0.51)

Blacktip shark, *Carcharhinus limbatus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	0.14 (0.30)
Juveniles	0.03 (0.12)	0.81 (2.32)	0.14 (0.42)	1.42 (1.71)
Adults	-	-	0.03 (0.13)	0.18 (0.41)
All	0.03 (0.12)	0.84 (2.41)	0.17 (0.45)	1.77 (1.86)

Bonnethead shark, *Sphyrna tiburo*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	0.03 (0.19)	0.02 (0.09)
Juveniles	0.06 (0.24)	0.59 (1.54)	0.12 (0.32)	0.02 (0.09)
Adults	0.24 (0.97)	0.21 (0.55)	0.21 (0.56)	0.46 (0.77)
All	0.29 (1.21)	0.80 (1.71)	0.38 (0.76)	0.50 (0.86)

Bull shark, *Carcharhinus leucas*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	-
Juveniles	-	0.05 (0.30)	0.07 (0.26)	0.02 (0.09)
Adults	-	-	-	-
All	-	0.05 (0.30)	0.07 (0.26)	0.02 (0.09)

Finetooth shark, *Carcharhinus isodon*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	0.04 (0.13)
Juveniles	-	-	-	1.24 (2.33)
Adults	-	0.02 (0.15)	-	0.42 (0.68)
All	-	0.02 (0.15)	-	1.69 (2.73)

Florida smoothhound, *Mustelus norrisi*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	-
Juveniles	-	0.05 (0.21)	-	-
Adults	-	-	-	-
All	-	0.05 (0.21)	-	-

Great hammerhead shark, *Sphyrna mokarran*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	-
Juveniles	-	0.02 (0.15)	-	-
Adults	-	-	-	-
All	-	0.02 (0.15)	-	-

Sandbar shark, *Carcharhinus plumbeus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	0.02 (0.09)
Juveniles	-	-	-	0.05 (0.21)
Adults	-	-	-	-
All	-	-	-	0.07 (0.26)

Scalloped hammerhead shark, *Sphyrna lewini*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	0.05 (0.21)	-	0.63 (1.14)
Juveniles	-	-	-	0.24 (0.57)
Adults	-	-	-	-
All	-	0.05 (0.21)	-	0.86 (1.41)

Spinner shark, *Carcharhinus brevipinna*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	0.23 (0.60)
Juveniles	-	0.07 (0.26)	0.03 (0.19)	0.70 (1.63)
Adults	-	-	0.03 (0.19)	-
All	-	0.07 (0.26)	0.07 (0.26)	0.93 (2.00)

Table 2. Summary of CPUE (number of rays/net/hour) for rays by major area sampled in the northeast Gulf of Mexico. Means (standard deviations) are presented. Young-of-the-year life stage includes neonates. Specimens with an undetermined life stage are included in total CPUE calculation. Species are listed alphabetically by common name.

Atlantic stingray, *Dasyatis sabina*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	-
Juveniles	-	-	-	-
Adults	-	-	0.03 (0.19)	-
All	-	-	0.03 (0.19)	-

Bluntnose stingray, *Dasyatis sayi*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	-	-	-
Juveniles	-	-	0.03 (0.18)	-
Adults	-	0.01 (0.07)	0.02 (0.09)	-
All	-	0.01 (0.07)	0.05 (0.20)	-

Cownose ray, *Rhinoptera bonasus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay
Young-of-the-year	-	0.02 (0.15)	0.05 (0.28)	0.09 (0.39)
Juveniles	0.29 (1.21)	-	-	0.16 (0.43)
Adults	0.24 (0.97)	0.07 (0.34)	0.79 (1.88)	0.29 (0.64)
All	0.53 (2.18)	0.09 (0.37)	0.86 (1.92)	0.60 (1.13)

Table 3. Summary of the habitat associations for the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (^{o}C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.1 (27.4-28.7)	34.0 (33.0-35.0)	4.6 (3.5-5.4)	212.5 (150.0-350.0)	5.5 (5.4-5.6)	Mud/Seagrass /Sand
Juveniles	26.7 (17.4-30.7)	31.5 (26.2-34.0)	3.9 (1.5-6.6)	223.6 (75.0-420.0)	5.6 (4.4-11.0)	Mud/Sand /Seagrass
Adults	27.1 (17.8-30.7)	32.0 (26.5-35.0)	4.2 (2.5-6.6)	222.0 (55.0-420.0)	5.7 (4.4-8.0)	Mud/Sand /Seagrass

Table 4. Summary of the habitat associations for the blacknose shark, *Carcharhinus acronotus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (^{o}C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.2 (29.3-31.4)	31.8 (29.9-34.0)	2.9 (1.5-4.5)	248.3 (150.0-400.0)	5.4 (4.5-6.4)	Sand /Seagrass
Juveniles	27.8 (27.5-28.0	34 -	2.4 (2.0-2.7)	225.0 (200.0-250.0)	6.1 (6.0-6.2)	Sand /Seagrass
Adults	30.1 (29.5-30.7)	32.6 (30.9-34.0)	4.1 (3.0-5.2)	143.3 (55.0-200.0)	5.4 (5.1-5.5)	Mud

Table 5. Summary of the habitat associations for the blacktip shark, *Carcharhinus limbatus*, by

life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.8 (24.9-30.4)	32.2 (30.5-34.0)	4.4 (3.0-5.2)	148.3 (55.0-350.0)	5.1 (4.5-5.5)	Mud
Juveniles	27.8 (19.2-30.7)	32.2 (28.5-35.0)	4.3 (2.2-6.0)	204.6 (55.0-420.0)	5.5 (4.3-7.9)	Mud/Sand /Seagrass
Adults	28.1 (24.1-30.5)	32.3 (29.3-35.0)	4.4 (3.5-6.0)	178.6 (75.0-350.0)	5.2 (4.3-6.0)	Mud/Sand /Seagrass

Table 6. Summary of the habitat associations for the bonnethead shark, *Sphyrna tiburo*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	24.7 (24.5-24.9)	32.3 (32.0-32.6)	3.1 (1.2-5.0)	115 (110.0-120.0)	5.5 (5.3-5.6)	Equal Sand, Seagrass, Mud
Juveniles	27.6	32.1	3.7	230.6	5.5	Sand, Equal Seagrass, Mud
Adults	27.0 (17.8-30.7)	31.4 (26.5-33.0)	3.9 (1.2-6.6)	191.3 (75.0-375.0)	5.6 (3.5-11.0)	Mud/Sand /Seagrass

Table 7. Summary of the habitat associations for the bull shark, *Carcharhinus leucas*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	- -	- -	- -	- -	- -	- -
Juveniles	30.0 (28.7-31.0)	33.1 (32.2-34.0)	3.4 (1.5-5.2)	222.5 (150.0-440.0)	5.4 (4.7-6.2)	Equal Mud, Sand
Adults	- -	- -	- -	- -	- -	- -

Table 8. Summary of the habitat associations for the finetooth shark, *Carcharhinus isodon*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	29.6 (28.7-30.4)	31.6 (26.5-35.0)	4.5 (3.0-6.0)	117.5 (75.0-160.0)	4.6 (4.4-4.7)	Mud
Juveniles	27.7 (17.8-30.4)	31.9 (26.5-35.0)	4.8 (3.0-6.6)	154.7 (55.0-350.0)	5.3 (4.4-6.3)	Mud
Adults	25.5 (17.8-30.5)	31.6 (26.5-35.0)	4.8 (3.0-6.6)	165.0 (60.0-370.0)	5.7 (4.3-8.0)	Mud/Sand

Table 9. Summary of the habitat associations for the Florida smoothhoud, *Mustelus norrisi*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	- -	- -	- -	- -	- -	-
Juveniles	28.8 -	30.8 (30.7-30.9)	4.6 (4.5-4.7)	387.5 (375.0-400.0)	5.1 (5.0-5.2)	Mud/Sand
Adults	- -	- -	- -	- -	- -	-

Table 10. Summary of the habitat associations for the great hammerhead shark, *Sphyrna mokarran*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	- -	- -	- -	- -	- -	-
Juveniles	29.0 -	32.7 -	3.0 -	280.0 -	4.9 -	Sand
Adults	- -	- -	- -	- -	- -	-

Table 11. Summary of the habitat associations for the sandbar shark, *Carcharhinus plumbeus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	29.5 -	34.0 -	5.2 -	55 -	5.50 -	Mud
Juveniles	29.5 (29.4-29.5)	33.3 (32.5-34.0)	4.6 (4.0-5.2)	202.5 (55.0-350.0)	5.2 (4.9-5.5)	Mud
Adults	- -	- -	- -	- -	- -	-

Table 12. Summary of the habitat associations for the scalloped hammerhead shark, *Sphyrna lewini*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	29.0 (24.9-30.4)	32.4 (30.9-35.0)	4.4 (3.0-6.2)	186.4 (50.0-420.0)	5.1 (4.4-6.2)	Mud/Sand
Juveniles	27.9 (26.1-29.5)	31.8 (30.0-35.0)	4.1 (3.0-6.0)	140.0 (60.0-290.0)	5.5 (4.4-6.3)	Mud
Adults	- -	- -	- -	- -	- -	-

Table 13. Summary of the habitat associations for the spinner shark, *Carcharhinus brevipinna*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.5 (24.9-30.7)	32.2 (31.3-33.0)	4.0 (3.0-5.0)	102.5 (50.0-175.0)	4.9 (4.4-5.3)	Mud
Juveniles	28.2 (19.3-30.7)	32.6 (30.9-34.0)	4.6 (3.0-6.7)	195.0 (55.0-370.0)	5.4 (4.3-7.9)	Mud/Sand /Seagrass
Adults	24.1 -	29.3 -	3.5 -	300.0 -	5.6 -	Sand

Table 14. Summary of the habitat associations for the Atlantic stingray, *Dasyatis sabina*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	-
Juveniles	-	-	-	-	-	-
	-	-	-	-	-	-
Adults	30.2	30.4	2.0	200.0	4.6	Seagrass
	-	-	-	-	-	

Table 15. Summary of the habitat associations for the bluntnose stingray, *Dasyatis sayi*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	30.6	35.0	2.0	200.0	4.9	Seagrass
	-	-	-	-	-	/Sand
Adults	23.1	32.5	2.3	225.0	6.5	Seagrass
	(18.2-28.0)	(31.0-34.0)	(2.0-2.5)	(200.0-250.0)	(6.0-7.0)	/Sand

Table 16. Summary of the habitat associations for the cownose ray, *Rhinoptera bonasus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage in the northeast Gulf of Mexico. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.1	34.0	4.6	212.5	5.5	Mud/Seagrass
	(27.4-28.7)	(33.0-35.0)	(3.5-5.4)	(150.0-300.0)	(5.4-5.6)	/Sand
Juveniles	27.4	32.2	4.2	145.0	6.2	Mud/Sand
	(18.8-30.6)	(30.1-35.0)	(2.2-5.5)	(75.0-200.0)	(4.7-11.0)	
Adults	27.4	31.9	3.8	185.0	6.1	Mud/Seagrass
	(18.8-30.6)	(29.3-34.0)	(2.0-5.6)	(60.0-350.0)	(4.6-11.0)	/Sand

Table 17. Summary of CPUE (number of sharks/net/hour) for sharks by life history stage and major area sampled in Mississippi Sound. Means (standard deviations) are presented. Young-of-the-year life stage includes neonates. Specimens with an undetermined life stage are included in total CPUE calculation. Species are listed alphabetically by common name.

Atlantic sharpnose shark, *Rhizoprionodon terraenovae*

Life stage	Round Island	Horn Island	Cat Island	Davis Bayou
Young-of-the-year	0.75 (-)	0.06 (0.11)	-	-
Juveniles	-	-	-	-
Adults	-	1.34 (0.62)	-	-
All	0.75 (-)	1.40 (0.54)	-	-

Blacktip shark, *Carcharhinus limbatus*

Life stage	Round Island	Horn Island	Cat Island	Davis Bayou
Young-of-the-year	-	1.00 (1.45)	0.13 (0.22)	-
Juveniles	-	0.68 (0.91)	0.34 (0.39)	-
Adults	-	-	0.08 (0.14)	-
All	-	1.68 (2.36)	0.55 (0.57)	-

Bull shark, *C. leucas*

Life stage	Round Island	Horn Island	Cat Island	Davis Bayou
Young-of-the-year	-	-	0.19 (0.33)	0.33 (-)
Juveniles	-	0.11 (0.19)	-	-
Adults	-	-	-	-
All	-	0.11 (0.19)	0.19 (0.33)	0.33 (-)

Finetooth shark, *C. isodon*

Life stage	Round Island	Horn Island	Cat Island	Davis Bayou
Young-of-the-year	-	-	0.06 (0.11)	-
Juveniles	0.75 (-)	0.06 (0.11)	-	-
Adults	-	-	-	-
All	0.75 (-)	0.06 (0.11)	0.06 (0.11)	-

Table 18. Summary of the habitat associations for Atlantic sharpnose sharks, *Rhizoprionodon terraenovae*, by life history stage sampled in Mississippi Sound. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.9 (27.8-30.0)	27.6 (25.2-30.0)	4.0 (2.7-5.3)	75.8 (30.5-121.0)	6.2 (5.9-6.6)	Silt/Clay /Sand
Juveniles	- -	- -	- -	- -	- -	- -
Adults	26.7 (26.5-27.8)	26.6 (23.5-29.0)	5.0 (4.3-5.5)	181.0 (121.0-244.0)	5.7 (2.0-8.2)	Sand/Silt /Clay

Table 19. Summary of the habitat associations for blacktip sharks, *Carcharhinus limbatus*, by life history stage sampled in Mississippi Sound. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	27.4 (26.5-28.1)	25.5 (23.5-29.0)	4.8 (4.3-5.3)	142 (121.0-178.0)	6.3 (5.9-7.0)	Sand/Silt /Clay
Juveniles	28.4 (26.5-31.3)	23.6 (18.0-29.0)	4.8 (4.3-5.3)	136.8 (121.0-178.0)	6.3 (5.9-7.0)	Sand/Silt /Clay
Adults	31.3 -	18.0 -	4.6 -	125.0 -	6.4 -	Sand/Silt /Clay

Table 20. Summary of the habitat associations for bull sharks, *Carcharhinus leucas*, by life history stage sampled in Mississippi Sound. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	27.5 (26.9-28.4)	18.4 (13.0-23.9)	3.0 (1.2-4.9)	71.3 (15.5-127.0)	5.7 (5.4-6.0)	Sand/Mud
Juveniles	26.5 -	23.5 -	4.3 -	178.0 -	7.0 -	Silt/Clay
Adults	- -	- -	- -	- -	- -	-

Table 21. Summary of the habitat associations for finetooth sharks, *Carcharhinus isodon*, by life history stage sampled in Mississippi Sound. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.1 -	23.9 -	4.9 -	127 -	6.0 -	Sand/Silt /Clay
Juveniles	28.9 (27.8-30.0)	27.0 (24.9-29.0)	4.0 (2.7-5.9)	75.8 (30.5-121.0)	6.2 (5.9-6.6)	Silt/Clay /Sand
Adults	- -	- -	- -	- -	- -	-

Table 22. Summary of the habitat associations for rays in Mississippi Sound. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Species	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Bluntnose stingray	28.9 (23.2-30.8)	28.3 (24.0-31.5)	2.7 (0.8-5.0)	202.8 (80.0-250.0)	5.5 (3.5-6.3)	Sand/Silt /Clay
Cownose ray	27.4 (20.2-32.2	29.1 (17.1-34.8)	3.1 (1.0-6.5)	207.8 (50.0-350.0)	5.5 (2.3-8.2)	Sand/Silt /Clay

Table 23. Summary of biological data on sharks collected in Timbalier Bay, La. Mean (ranges) are presented. Species are listed alphabetically by common name.

Species	Total Collected	Sex Ratio M:F	Fork Length (cm)
Atlantic sharpnose shark	1	1:0	135.4 -
Blacktip shark	6	2:4	99.5 (95.0-108.5)
Bull shark	67	32:35	49.4 (44.0-64.5)
Finetooth shark	1	1:0	30.4 -

Table 24. Summary of the habitat associations for the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, by life history stage sampled in Timbalier Bay, La. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.0	19.1	2.0	28.0	4.86	Mud/Shell
	-	-	-	-	-	
Juveniles	-	-	-	-	-	-
	-	-	-	-	-	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 25. Summary of the habitat associations for the blacktip shark, *Carcharhinus limbatus*, by life history stage sampled in Timbalier Bay, La. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	29.7	21.9	1.9	59	4.26	Mud/Shell
	(28.9-30.6)	(19.2-23.0)	(1.5-2.2)	(40.0-103.0)	(3.68-4.75)	
Juveniles	-	-	-	-	-	-
	-	-	-	-	-	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 26. Summary of the habitat associations for the bull shark, *Carcharhinus leucas*, by life history stage sampled in Timbalier Bay, La. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	29.7	21.9	1.25	59.0	4.26	Mud/Shell
	(28.9-30.6)	(19.2-23.0)	(1.0-1.5)	(40.0-103.0)	(3.68-4.75)	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 27. Summary of the habitat associations for the finetooth shark, *Carcharhinus isodon*, by life history stage sampled in Timbalier Bay, La. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	-	-	-	-	-	-
	-	-	-	-	-`	
Adults	29.4	23.0	1.8	40.0	4.32	Mud/Shell
	-	-	-	-	-	

Figure 1. Locations of sets made in 2004 for areas in the northeast Gulf of Mexico, Florida.

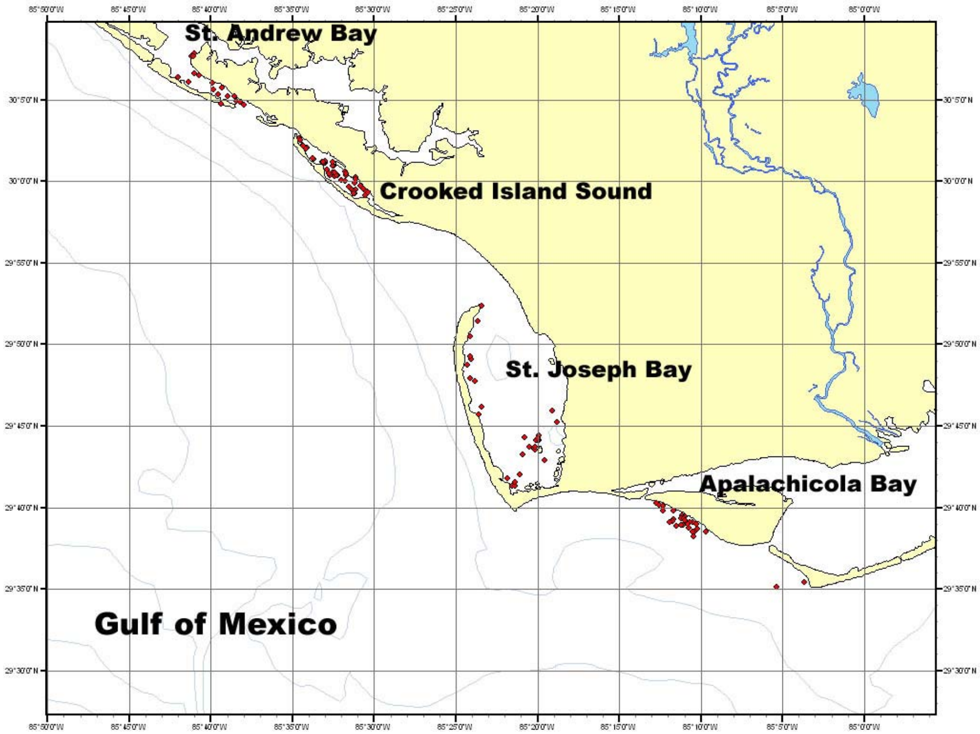

Figure 2. Locations of sampling stations in 2004 for areas in Mississippi Sound.

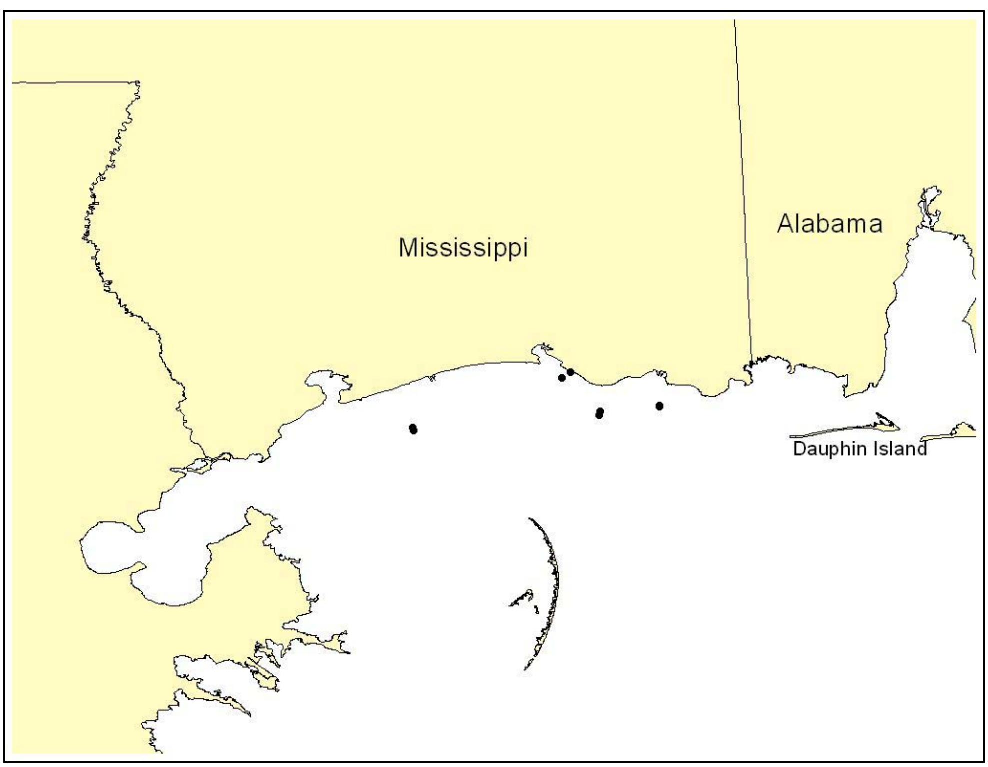

Figure 3. Sampling locations within Timbalier Bay, Central Louisiana for the 2004 sampling season.